Small Hydro

Montana's Energy Resources

VOLUME 2

HYDROPOWER IN MONTANA

Harnessing the energy in falling water is not new to Montanans. Early small-scale hydro projects pumped water for irrigation and mining, turned sawmill blades, and generated electricity for remote farms, homesteads and factories. On a larger scale, beginning in the late 1800's, dams were built on the Missouri River to supply power to hoist ore from mine shafts, to compress air for lead and copper smelters and to provide electric lights for the growing cities. Although most large-scale sites have now been developed, the small-scale hydro potential of the state's many rivers and streams is still untapped. Small-scale hydro includes projects with a generating capacity between 100 kilowatts and 1 or 2 megawatts; micro-hydro projects are those systems having power outputs of less than 100 kilowatts.

If you're thinking of starting a small hydropower project, this factsheet will give you some basics on small-scale hydropower and will tell you where you can get more information.

ACCESSIBILITY TO THE LAND

Although most project developers will own the land on which the project will be located, others will need to secure those rights from the landowners. The system's intake may have to be located on land owned by a state or federal agency or by another private party. In other cases, both intake and powerhouse may sit on the project developer's land, but the penstock that connects them might cross someone else's property.

The feasibility of an entire project should be determined before any purchase or lease agreements are arranged. Also, if it is known that the property in question is not available under any circumstance, alternate plans should be considered.

DETERMINING SITE POTENTIAL

In order to determine the hydro potential of your site, information regarding amount and variation of streamflow is essential. You should find out if streamflow records have been kept for the stream at any time. A good place to begin inquiries is with the U.S. Geological Survey (USGS), Federal Building, Helena, MT 59626; phone 449-5263.

If historic flow records are not available, you should immediately begin monitoring the streamflow at the site; the feasibility of constructing a small power plant is dependent on exactly how much power your stream will put out. The two most important factors to consider are flow and head.

Flow is the quantity of water flowing past a point at any given time. This amount varies both seasonally and annually, so it is important to collect accurate data for each season of a full year. These data should then be compared to USGS information from your area to decide if it was a dry year or a wet year. You can obtain snow pack information for your area by contacting the U.S.D.A. Soil Conservation Service Snow Survey Unit, P.O. Box 98, Bozeman, MT 59715; phone 587-5271. Minimum flow rates are necessary to accurately assess the minimum continuous power output to be expected from your hydro unit. Also, maximum flow estimate is necessary to ensure that your structure will be able to withstand peak flooding.

Head is the vertical distance in feet from the surface of the supply water to where the water leaves the turbine. The head exerts pressure that can be turned into usable power, so the greater distance the water falls, the more energy is available.

Low head is considered to be less than 60 feet; high head is 60 feet or more. Although there are exceptions, ten feet of head is usually the minimum amount necessary to generate power.

Once you have determined the net head and the average flow rate for your particular site, you can calculate the power output from your stream.

DETERMINING ENERGY NEEDS

A central question to project feasibility is whether or not the site will produce enough power to meet your energy needs. Two types of energy estimates should be evaluated—peak demand and total consumption. Peak demand is the maximum power needed at any one time. In household use peak demand occurs when all electric loads are on at once. Total consumption is the number of kilowatt-hours used in a given period. Utility companies usually use the measure kilowatt-hours per month.

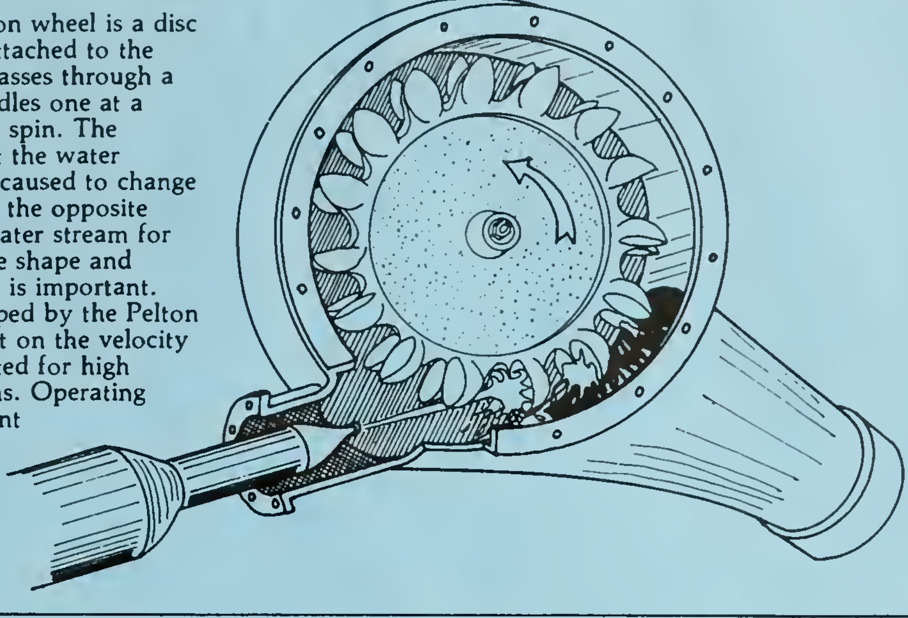
A system capable of meeting total consumption will not necessarily cover peak power needs; consumption or power needs may have to be adjusted. If your power needs are greater than your potential energy source, you may consider storing electricity in batteries or buying extra electricity from the utilities to supply peak demand needs. Contact your nearest Montana utility to seek assistance early in the process.

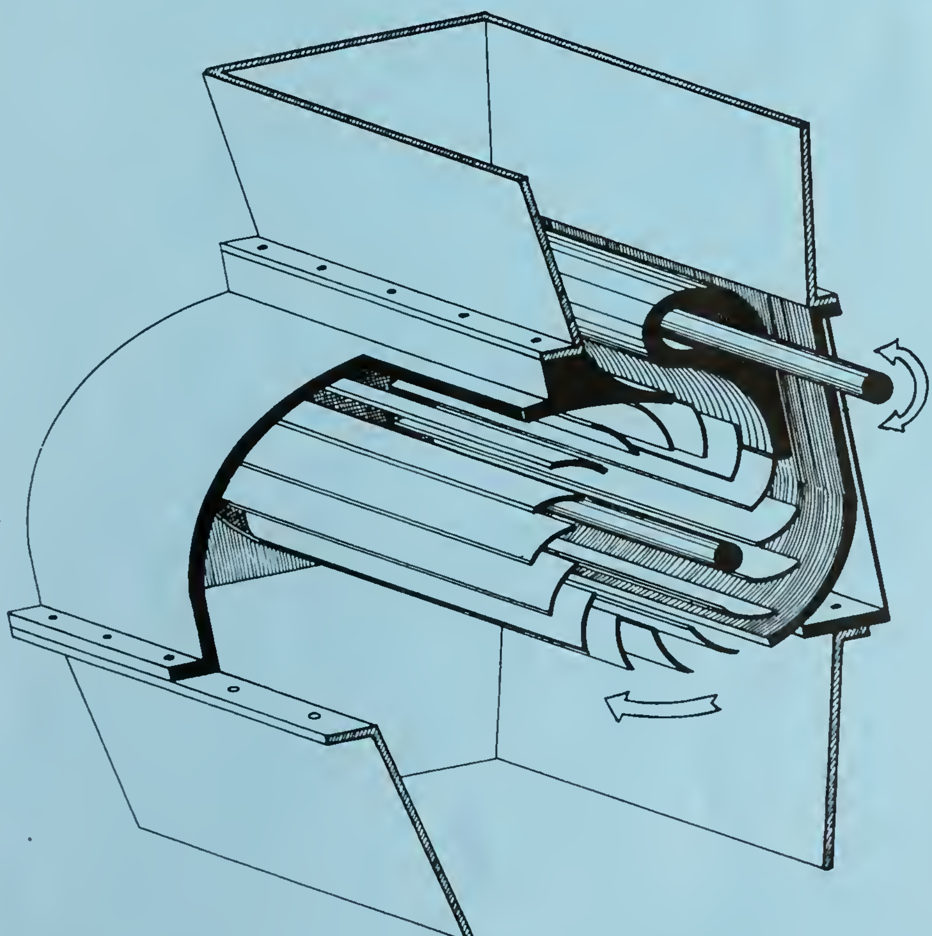
For more information on determining stream head and flow, calculating the power output of your stream, and determining your energy needs, contact the Energy Division, Montana Department of Natural Resources and Conservation, 32 South Ewing, Helena, MT 59620; phone 444-6696.

TYPES OF SYSTEMS

The Pelton Wheel

In general terms, a Pelton wheel is a disc with paddles or buckets attached to the outside edge. The water passes through a nozzle and strikes the paddles one at a time, causing the wheel to spin. The buckets are shaped so that the water stream is split in half and caused to change direction, heading back in the opposite direction to the original water stream for the greatest efficiency. The shape and smoothness of the buckets is important. Because the power developed by the Pelton Wheel is largely dependent on the velocity of the water, it is well suited for high head/low flow installations. Operating efficiencies in the 80 percent range are common and micro units using the Pelton Wheel are produced by several firms in North America.



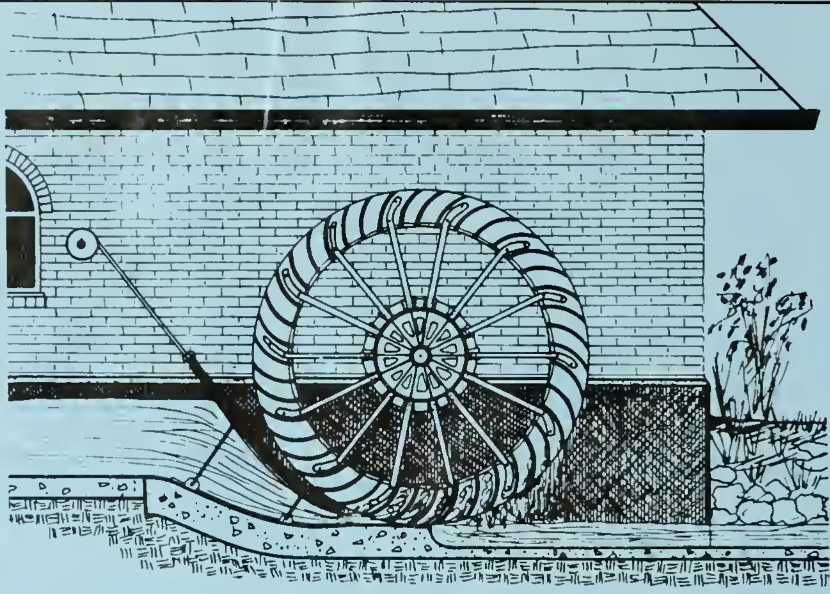


The Crossflow Turbine:

A crossflow runner is drum-shaped with the blades fixed radially along the outer edge. The unit, open in the center, resembles a "squirrel cage" blower. When looked at from the end as though it were a clock face, the water enters at 9 o'clock, crosses the center and exits at 4 o'clock; thus the name crossflow. Most commercially available crossflows are made by Ossberger of West Germany or by someone else under their license. Because of its design, the crossflow is said to be largely self-cleaning and is well suited to low head applications. Ossberger has, in fact, installed them successfully in situations with only 39 inches (1 meter) of head. The Ossberger crossflow uses a metering vane at the intake side and maintains high efficiency over a wide range of flow rates. Because the runner and housing fit fairly close, a draft tube is used on the down side of the turbine, allowing some flexibility in installation relative to turbine placement and tail water level. The crossflow is used widely around the world, although it is less common in the United States.

Poncelet Wheel:

This is an adaptation of the undershot wheel, in which the blades are curved to provide more efficient water interaction with the wheel. This wheel makes use of the velocity of the water which has been held back and forced through a narrow opening. Minimum diameter of a Poncelet Wheel is about 14 feet and they usually operate best with heads of 7 feet or less. Efficiencies are higher than for the undershot wheel. These wheels require a breastworks of concrete fitted close to the rim of the wheel in order to help retain water in the buckets. The close clearances necessitate the use of trash racks to keep stones and wood from entering the system and causing damage.



Drawings on pages 3, 4, and 5 reprinted with permission from **Micro-hydro Power: Reviewing an Old Concept**, Ron Alward, Sherry Eisenbart, John Volkman and Hans Haumberger, National Center for Appropriate Technology, Butte, 1979.

Water wheels and water turbines are two basic types of hydropower machines. Water wheels are the traditional devices used to convert the energy in flowing and falling water into mechanical power. They are used in grinding grain, and operating saws, lathes, drill presses, and pumps. Usually large in diameter and slow turning, water wheels work well in streams with large variations in stream flow. Trash racks and screens are usually not needed because sticks, stones, and dirt will flow over the wheel in the stream of water. Water wheels can be used to produce electricity, although the large diameter and slow rotation requires the rotational shaft to be geared up to a much higher RPM.

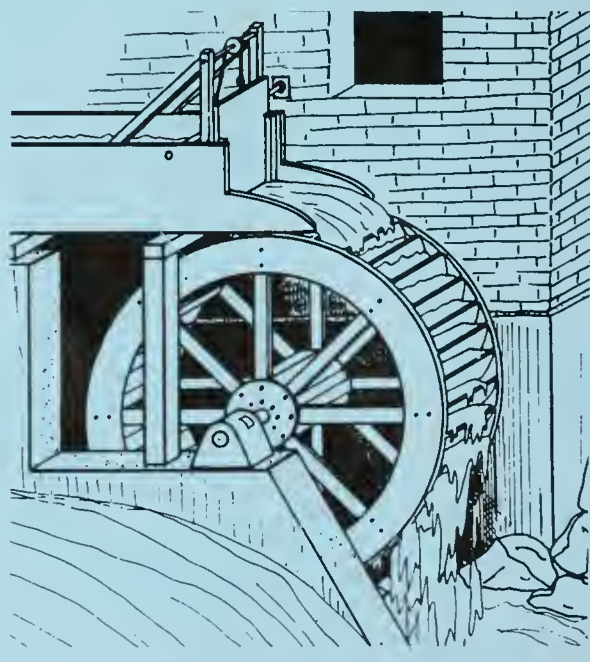
Because water wheels operate at slow speeds, they are considerably less efficient than water turbines in producing electricity. Water wheels are also bulky and in harsher climates have to be housed in large structures to avoid ice buildup in the winter.

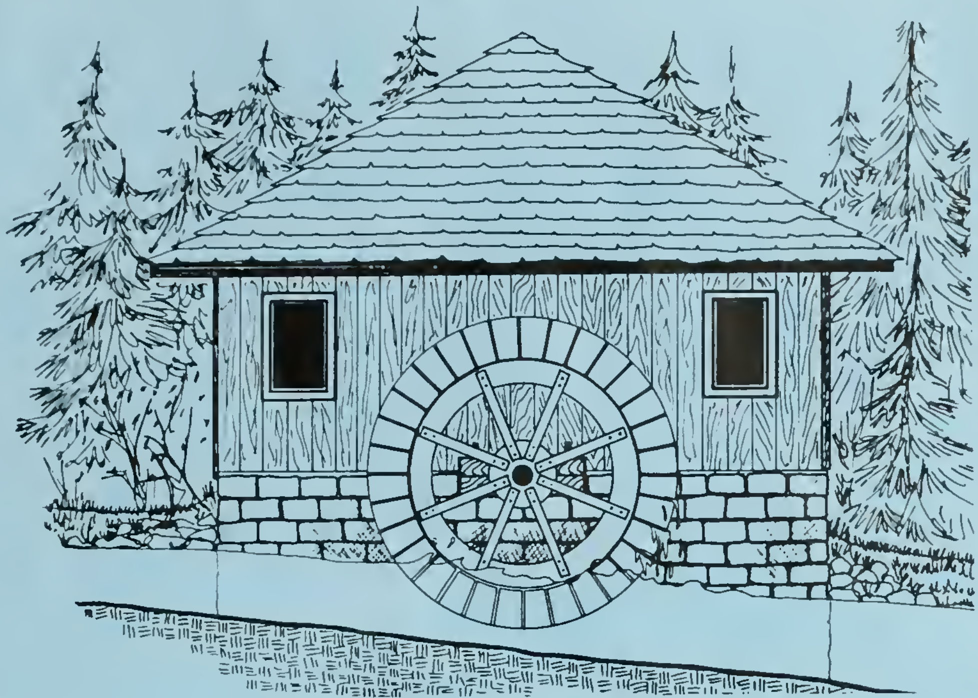
Water turbines spin at high speeds, are used for electrical generation and can be as high as 70-80% efficient in producing mechanical or electrical energy. While water wheels use water carried in an open flume or channel, turbines receive their energy from water carried in pressure conduits. Water turbines are complicated pieces of equipment and must be carefully installed.

Also, debris such as rocks, sticks and sand can interfere with the blades, so a trash rack or screen is required to prevent this material from going through the turbine.

Overshot Wheel:

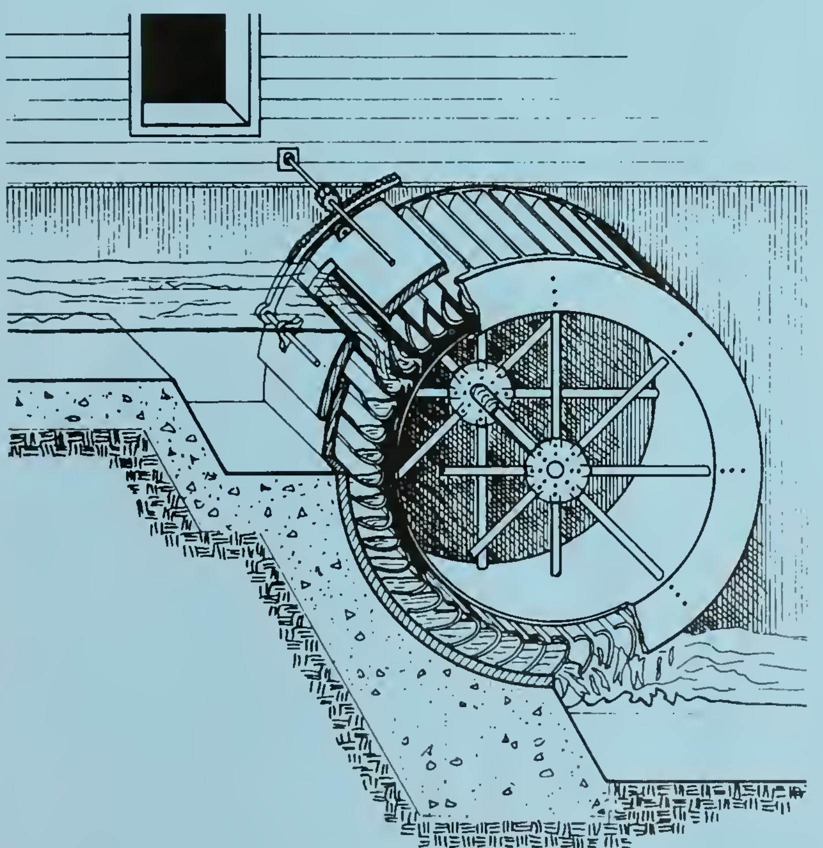
Water is supplied by a nearly horizontal chute to the top of the water wheel. The weight of the water in the rim buckets causes the wheel to turn. The entering water usually strikes the buckets with a velocity somewhat greater than the rim speed so as not to be struck by the back of the buckets and be splashed off the wheel. The water supply, and thus the power output, is controlled by a hand- operated sluice gate. Overshot wheels are generally the most efficient of the water wheels. They can operate on any head above 10 feet. Today, the upper limit on the head is around 30 feet because of the cost of constructing a wheel of that diameter.





Undershot Wheel:

This is the most basic of water wheels. Water passing under the wheel strikes the blades or paddles, causing the wheel to rotate. It can operate on a minimum of one foot of head (producing almost no power at this head), and has a low efficiency. The optimum head range is 6 to 15 feet, with minimum wheel diameter being about 15 feet.



Breast Wheel:

Water enters the breast wheel below the top of the wheel and is kept in the buckets by a close fitting breastworks until it discharges at or near the lowest point on the wheel. Breast wheels operate best with heads less than 10 feet, and wheel diameters usually range between the head and three times the head. High breast wheels (water entering above the center shaft) have efficiencies that can approach 65 percent. Low breast wheels (water entering below the center shaft) usually have efficiencies between 35 and 40 percent.

Breast wheels require somewhat complicated, curved breastworks. In addition, the buckets have to be ventilated to allow air to escape to the next higher bucket as each bucket fills. The close tolerances of the breastworks give the same disadvantages in terms of water-borne debris as for the Poncelet wheel. The complicated construction techniques and the lower efficiencies, particularly in the low breast wheels, usually make other types of water wheels more attractive.

SYSTEM COMPONENTS

A typical micro-hydro system consists of several components. An intake structure controls the flow of diversion water to be used. A penstock or flume carries the water from the intake structure to the turbine. The power house contains the water turbine, generator and contols.

CALCULATING THE COST

Once the head, flow and system output are known, you can contact equipment suppliers to get accurate cost data. There is no point in contacting these people before the site details are known, as costs of equipment would vary considerably with different sites.

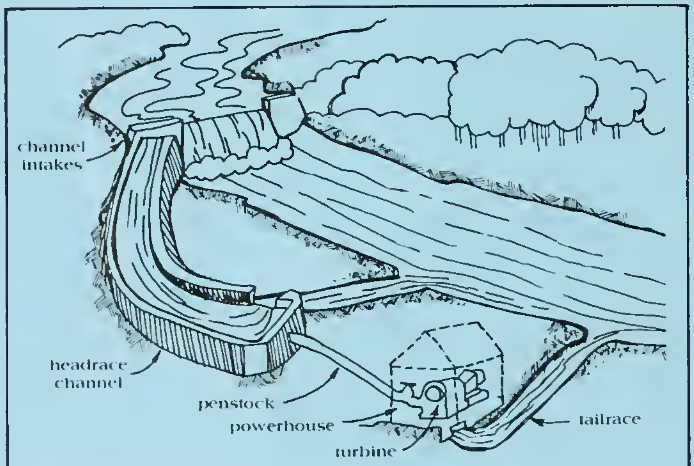
The following list will give you an idea of materials to be included in your cost estimate.

Construction materials:
- Lumber (powerhouse)
- Concrete (penstock, trailrace, intake foundations)
- Trash racks

Generating materials:
- Penstock: pipe, including elbows and gate valves, trash racks
- Turbine
- Generator
- Inverter
- Breaker box
- Storage batteries

Transmission materials:
- Transmission lines
- Transmission poles and insulators
- Electrical connections

Costs vary widely with each site and size of system. Typical costs range from $1,000 to $3,000 per kilowatt, installed.



A typical installation for a small hydroplant. Reprinted with permission from **Other Homes and Garbage**, Jim Leckie, Gil Masters, Harry Whitehouse and Lily Young, Sierra Club Books, San Francisco, 1975.

ENVIRONMENTAL CONSIDERATIONS

Water wheels and water turbines alone have a negligible effect on the environment. Most hydro systems, however, require a dam to ensure a continuous source of water. Damming a river or stream can have a long-term effect on the environment surrounding the site. Streamflow is changed, and the water table is usually raised behind the dam and lowered downstream from the structure. You are creating a pond or lake where a stream ecosystem used to exist, so silt may accumulate and you may have constructed an ideal breeding ground for mosquitos. Fish movement may be blocked if a fish ladder isn't used. Access roads may contribute to erosion and disrupt the landscape. In general, the larger the dam, the greater the impact on the environment. If you foresee the ecological impact of installing a hydroplant, you can keep stream disruption to an absolute minimum. Keep in mind that you may have to radically change your design to work with your local ecosystem or, in some cases, abandon the hydropower project completely.

PERMITTING AND LICENSING

Before you do any construction on your stream, you should be aware of the regulatory conflicts you may face. A variety of institutional and legal barriers exist and your project will go much smoother if these potential problems are identified early in the schedule so you can take the required actions.

Although numerous agencies have potential permitting or review authority, small hydropower projects are likely to require only a few permits. Nevertheless, the time required for obtaining all permits and licenses may be a major part of the project duration, so it is important for you to begin the permitting process in the early stages of developing your site.

Local Permitting Requirements

First of all, you should contact local government offices to determine local permit requirements. The local city and county planning and public works departments can tell you which permits are needed. All local permits or requirements must be satisfied before federal hydropower licenses will be issued. Generating facilities affecting only the developer's property should encounter few problems.

State Permitting Requirements

A hydropower developer in Montana probably will have to obtain at least two permits: a water right permit from the Water Resources Division of the Department of Natural Resources and Conservation (DNRC), and a "310" permit from the DNRC Conservation Districts Division (applications for a 310 permit are available from your local Conservation Districts Office). Other state agencies that may require permits or otherwise act in a review capacity include: the Department of Health and Environmental Sciences, the Department of State Lands, the Department of Fish, Wildlife and Parks, and the DNRC Engineering Bureau.

For more information and addresses for permitting, write to the Energy Division for the "Guide to Developing Hydropower in Montana," or contact the Montana Joint Water Resources Research Institute, Montana State University, Bozeman, MT 59717 for their publication titled "Montana Hydropower—A Manual for Site Development."

Federal Permitting Requirements

The Federal Energy Regulatory Commission (FERC) is the federal agency responsible for issuing licenses for non-federal hydroelectric projects under its jurisdiction. A hydropower project must obtain a license or an exemption from licensing if any of the following apply: 1) the project will use water from a navigable waterway, 2) power from the project will enter into an interstate utility grid system, 3) the project in whole or in part is located on land, 4) the project will use surplus water or waterpower from a federal dam. Check with FERC to see what licensing may be required in your case. A small self-contained project may not require FERC permitting, although all projects connected to a utility will.

CASCADE CREEK, MONTANA

After monitoring his site for a full year, Tom Budde received a grant from the Department of Natural Resources and Conservation to install a 65 kW hydro plant on Cascade Creek in the Paradise Valley. The grant has provisions for repayment, based on revenue Budde receives by wheeling his hydro-generated electricity through Park Electric Cooperative's lines to the Montana Power Company. Budde's system cost $90,000, nearly one-fourth of which was for the pipeline alone. But he expects to generate about $20,000 worth of electricity a year from his micro-hydro power plant.

The project is a run-of-the-river system which means the power output is dependent on the amount of streamflow. In the winter, Budde expects to produce about 25 kW of electricity and use 100% of the streamflow, while summer generation will be about 65 kW using only 20% of the available water.

Tom Budde's micro-hydro power production plant seems amazingly simple. He built a small dam, 4 feet high and 15 feet wide, on Cascade Creek, creating a small pond deep enough to avoid freezing problems. From there, a six-inch pipe carries the water down to the small building built next to his house that contains the commercially built turbine.

From the pond, water drops over 860 vertical feet and travels a bit over a mile at a rate of about 5 mph through the pipe. Just upstream from the turbine, the water goes through a nozzle, which pressurizes and reduces it into a small one-inch wide jet traveling at 160 mph.

The water then gushes out at a series of cups attached to the end of 20 metal spokes, like a water wheel, turning the hub shaft up to a maximum speed of 1,800 revolutions per minute. The shaft ac-

tivates the generator, creating a steady flow of electricity. All of the water returns to the stream after leaving the powerhouse, with no significant drop in water quality.

The Cascade Creek hydropower project took over two years to complete. Much of that time was spent securing the county, state, and federal permits necessary to proceed with the construction. And Budde's permitting process went easier than most since the power plant is located entirely on his own ranch. Allowing plenty of time for all phases of the project is important because, as Tom Budde stated, "there is a fast learning curve" for micro-hydro developers.

FOR MORE INFORMATION

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